

***Grade Control And Alluvial Fan Enhancement Measures To Prevent Loss Of Existing Channel Function And Enhance Flow Dissipation On Existing Alluvial Fans, Following The 2019 Museum Fire On The Coconino National Forest***

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The Museum Fire BAER report indicates that the fire burned mostly within a 4.8 square mile portion of the Spruce Avenue Wash watershed. Approximately 40% of the burned area was severely or moderately burned. Peak discharge as well as total water yield is predicted by the BAER team report to increase dramatically with expected peak flows up to 100 times higher than prefire conditions.

Pre-burn, Spruce Avenue Wash runoff amounts were typical of the area, with little or no runoff generated by all but the largest rainfall events (Hill, Hale and Aldrige, 1988). The porous channel bed and the large alluvial fan system with dispersing channel flow helped to capture and dissipate discharge events before they left USFS boundaries and entering private lands within Coconino County and the City of Flagstaff. Because discharge is low, sediment transport in the pre-burned conditions was low or discontinuous. Sediment output from unburned Coconino National Forest Lands is generally very low with most flows into the County 'clear'.

With increased flow will come increased sediment transport and erosion potential. Sediment that has accumulated in channels and on alluvial fan under the pre-fire hydrologic conditions will become mobilized during a high flow runoff event. Experience from the Schultz Fire and fires in other areas of the Southwest has shown that large scale flooding can incise alluvial fans and existing channels rapidly and change the channel functions drastically. Relatively wide, shallow channels with low flood plains can be incised to narrow deep gullies with unstable banks that source sediment over many decades as they evolve back to a stable condition. Worse, alluvial fan systems that normally serve to actively store sediment and dissipate flows can incise through to become large sediment sources that rapidly transport sediment and flows downstream. Loss of channel function due to incision during post fire runoff is a very real possibility in this region which can lead to long-term loss of watershed function and negative impacts to hydrology and sediment transport functions of the downstream watershed within the forest as well as damage to private property and public infrastructure beyond.



*Deeply incised channel in alluvial fan created by post fire flooding (Schultz Fire, Coconino County, AZ)*

The watershed channels have been initially surveyed for points with overly steep channels and confined floodplains that have a high probability of erosion. Areas of highest priority are located downstream of large lobes of sediment which could be mobilized or in larger alluvial fan systems that could be degraded by further incision. The potential fan enhancement areas are identified by relatively wide valley features with significantly lower slope than upstream reaches. These areas have incised channels through the valley bottom which were created either anthropogenically or through longtime degradation since the last fan building period. Recommendations provided herein are preliminary and will require additional field survey and analysis to properly size, locate and construct.

A high priority area for a potential head cut was identified near the City of Flagstaff boundary that has both a City water main and a Kinder Morgan high pressure gas line that serves the Flagstaff community. Both buried lines were deemed at risk of exposure and damage if a headcut migrated up the channel so the City of Flagstaff, in cooperation with USFS constructed rock grade control structures. As explained above this area has other opportunities for enhancement. While steeper areas, higher in the watershed are additional candidates for grade control, they may also be prone to debris flow activity which could either bury or scour the weir material away. These areas are being monitored more closely and may be candidates for work in the future.

Planned grade control practices consist of construction of cross vane weirs built at the grade of the existing channel. The weirs are constructed of large dense rock (~48-inch diameter) sized to resist movement at design discharges. The vane arms rise up slightly to the flood plain elevation (bankfull) and extend downstream to the width of the active channel (10 to 15 feet wide in most of the target channels). The vane arms are then buried into the flood plain for several feet to prevent erosion around the structure. The configuration works to hold grade, recenter flows into the existing channel and allow passage of sediment through the weir section. This design practice is installed to maintain the current

channel configuration, depth and function rather than slow sediment transport, spread flows or redirect flows.



*Rock weirs constructed for grade control in previously incised channel (Schultz Flood Area, AZ)*



*Rock weir constructed for headcut grade control, one year post construction. Lee Valley, AZ.*

The goal is to maintain and protect the current valuable channel function and elevation through highly erosive post fire flows. Examples of cross vane weir installations are provided in the figures above.

Installation of the weirs will require a source of large dense, weed free rock. Most rock in the burn area is lower density andesite or rhyolitic. Nearby sources of Malpais basalt are more appropriate. The rock is installed by an excavator fitted with a 'thumb' attachment that digs the weir trench and installs the boulders and backfill materials. Some engineering analysis is required to properly locate the weir, determine proper dimensions to maintain channel function and properly size the rock material to resist movement. Installation of these types of weirs can generally be accomplished by a competent operator and laborer at the rate of least one per day once the rock has been delivered to the site. Seeding of disturbed areas with native grass seed is highly recommended once installation is accomplished.

Planned alluvial fan enhancements include plugging existing incised channels to force flows onto the old alluvial fan surface. Material for channel plugging can come from two different potential onsite locations. If not available from channel construction or enlargement at the site, the plug material will need to come from a borrow area at either end of the proposed fan. This borrow area would help to create sediment storage in the short term by refilling with sediment transported by discharges from the burn area. Long-term sediment storage would be on the fan surface or in the old channel between plugged sections. Implementation would require heavy equipment operations as well as the removal of most trees in excavated or filled areas. The amount of excavation required would be determined after a detailed topographic survey and engineering analysis of each site.

Installation of grade control features prior to incision is highly recommended in an attempt to avoid costly repairs to alluvial fans and channels later. Additionally, initial field survey work identified tow alluvial fan systems that have been degraded by erosion and land manipulation that can be restored to enhance their ability to capture flow and debris. These alluvial fan enhancement areas are located along the border between Coconino National Forest land and private lands and provide an opportunity to restore natural processes on forest lands that can alleviate damage on private lands. One of the alluvial fan enhancement areas is located on a relatively large (40 acre) parcel of privately owned land adjacent to the national forest. This parcel also contains channels with high probability of erosion and should also be considered for grade control practices. For practical purposes, the potential work areas are divided into three (3) main areas:

- Coconino National Forest above Mount Elden Estates – this area is a working alluvial fan with multiple incised channels along the base. Grade control structures are highly recommended at multiple locations.
- APN 300-48-017 /40 acre private parcel above Mount Elden Estates – this area has the potential for alluvial fan enhancement (3 to 5 acres capturing flows from a 0.7 square mile watershed on the western side of the burn area) as well as repair and/or stabilization of incised channels on the lower portion of alluvial fan receiving flows from main burn area.
- Paradise Road Area / Coconino National Forest land immediately upstream of the Flagstaff city limits – this area has already received grade control structures to protect water and gas mains, but has an alluvial fan area which is incised by previous channel dredging that can be restored as well as a short section of undersized channel at the city limits which should be enlarged to accommodate post fire peak discharges.

The combination of landownership and authorities will create a need for cooperative work with multiple funding sources. This project overview is meant as a scoping document to illustrate the various practices that could be utilized on these locations to maintain/enhance the current channel functions which do serve to reduce sediment and debris from relatively frequent flood discharges from the fire burn area. A guiding principle for any of the work should be that it does not create additional risk for downstream areas. Therefore, flow should enter private lands in similar areas to the current condition. This concept does not address improvements that might be required on private lands through developed areas. Channel capacity, road stability and erosion control on these areas will likely need to be addressed as well by the various entities involved.

Conceptual/budgetary level costs for each of the three areas are provided below. These costs are based on current market costs for similar work in the region with an additional 15% engineering design cost and a 15% contingency. No cost has been evaluated for permitting or archaeological/biological work to support environmental analysis. Nationwide permits for emergency watershed protection are available for this situation and there may be an argument for exclusion of the area from jurisdictional limits based upon past USGS studies. These budgetary numbers assume all rock must be transported from a quarry located 30 miles north of Flagstaff. There can be considerable cost savings if nearby sources of rock can be identified on the forest and USFS crews can be utilized for installation on USFS lands.

#### Literature Cited-

Hill, G. W., T.A. Hales and B. N. Aldrige. 1988. Flood Hydrology near Flagstaff, Arizona. Water Resources Investigations Report 87-4210. U.S. Geological Survey. Tucson, AZ.

#### Conceptual Level Budget

##### Conceptual Level Budget

##### Museum Fire Pre-Flood Grade Control and Fan Enhancements

Coconino National Forest abv Mt. Elden Estates	Quantity	unit	Rate	Total
<i>Mobilization/Demobilization</i>	1	ls	\$4,000.00	\$ 4,000.00
<i>Purchase/Deliver Rock</i>	704	cu yd	\$ 250.00	\$176,000.00
<i>Install Grade Control</i>	22	ea	\$5,984.00	\$131,648.00
<i>Revegetation and weed treatment</i>	1	ls	\$8,000.00	\$ 8,000.00
<i>Access road and close out</i>	3	days	\$6,300.00	\$ 18,900.00
<i>Tree removal</i>	20	ea	\$ 800.00	\$ 16,000.00
<i>Engineering costs (15%)</i>				\$ 47,947.20
<i>20% contingency</i>				\$ 70,909.60
<i>Taxes</i>				\$ 26,803.83
<i>Total</i>				\$500,208.63

#### 40 Acre Private Parcel above Mt. Elden Estates

<i>Mobilization/Demobilization</i>	1	ls	\$4,000.00	\$ 4,000.00
<i>Purchase/Deliver Rock</i>	480	cu yd	\$ 250.00	\$120,000.00
<i>Install Grade Control</i>	15	ea	\$5,984.00	\$ 89,760.00
<i>Revegetation and weed treatment</i>	1	ls	\$8,000.00	\$ 8,000.00
<i>Access road and close out</i>	2	days	\$6,300.00	\$ 12,600.00
<i>Tree removal</i>	80	ea	\$ 800.00	\$ 64,000.00
<i>plug construction</i>	750	cu yds	\$ 144.00	\$108,000.00
<i>purchase rock for plug</i>	75	cu yds	\$ 103.00	\$ 7,725.00
<i>trench excavation</i>	750	cu yd	\$ 20.00	\$ 15,000.00
<i>Engineering costs (15%)</i>				\$ 64,362.75
<i>20% contingency</i>				\$ 85,817.00
<i>taxes</i>				\$ 32,438.83
<i>Total</i>				\$611,703.58

**Coconino National Forest above Paradise Road**

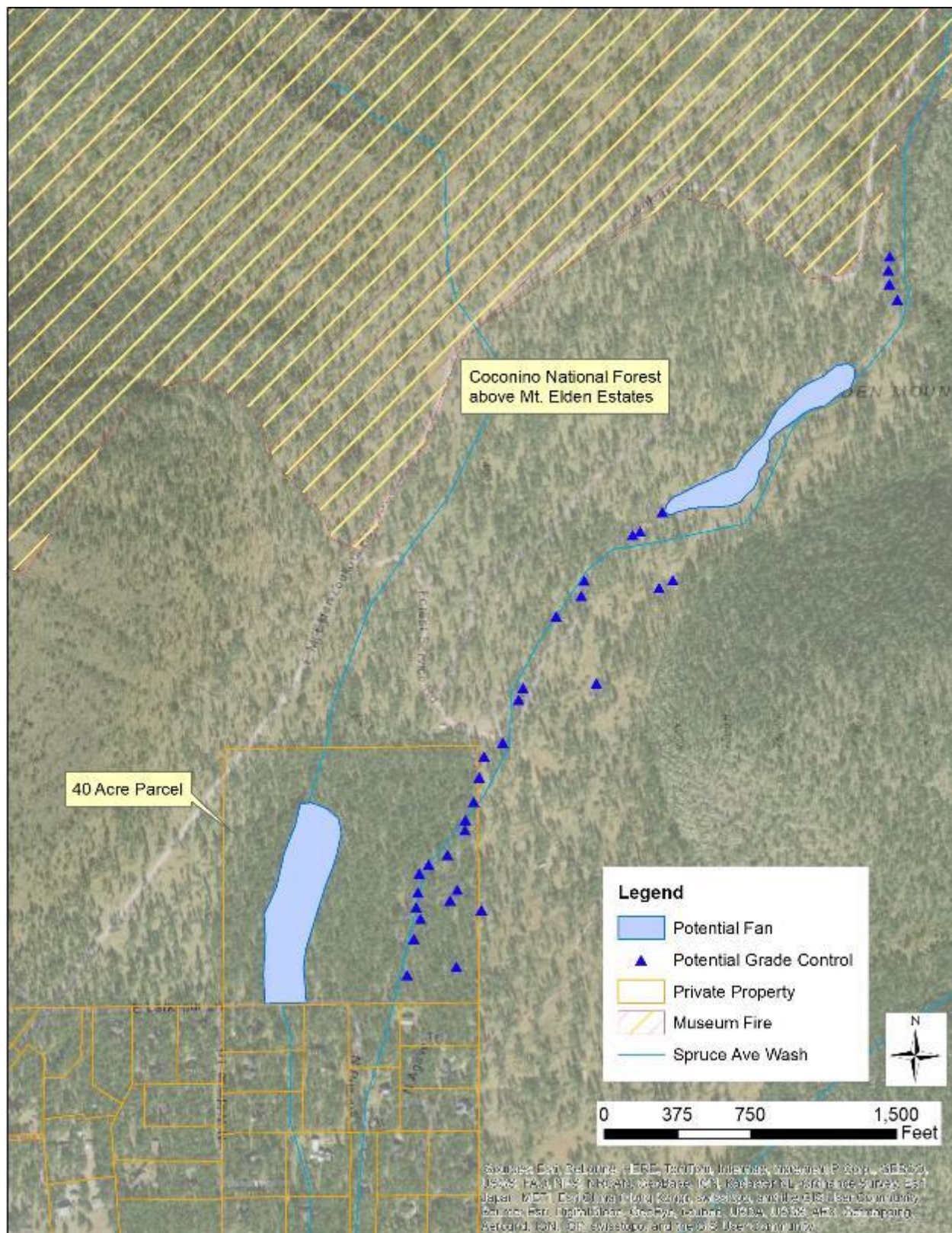
<i>Mobilization/Demobilization</i>	1	ls	\$4,000.00	\$ 4,000.00
<i>Revegetation and weed treatment</i>	1	ls	\$8,000.00	\$ 8,000.00
<i>Access road and close out</i>	2	days	\$6,300.00	\$ 12,600.00
<i>Tree removal</i>	15	ea	\$ 800.00	\$ 12,000.00
<i>plug construction</i>	750	cu yds	\$ 144.00	\$108,000.00
<i>purchase rock for plug</i>	75	cu yds	\$ 103.00	\$ 7,725.00
<i>Channel excavation</i>	750	cu yd	\$ 20.00	\$ 15,000.00
<i>Engineering costs (15%)</i>				\$ 25,098.75
<i>20% contingency</i>				\$ 33,465.00
<i>tax</i>				\$ 12,649.77
<i>Total</i>				\$238,538.52





### Overview of Potential Treatment Areas





*Private and Coconino National Forest Land above Mount Elden Estates*



